

# Renewed activity from the X-ray transient SAX J 1810.8-2609 with *INTEGRAL*<sup>1</sup>

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## ABSTRACT

We report on the results of *INTEGRAL* observations of the neutron star low mass X-ray binary SAX J1810.8-2609 during its latest active phase in August 2007. The current outburst is the first one since 1998 and the derived luminosity is  $1.1 - 2.6 \times 10^{36} \text{ erg s}^{-1}$  in the 20–100 keV energy range. This low outburst luminosity and the long-term time-average accretion rate of  $\sim 5 \times 10^{-12} M_{\odot} \text{ yr}^{-1}$  suggest that SAX J1810.8-2609 is a faint soft X-ray transient. During the flux increase, spectra are consistent with a thermal Comptonization model with a temperature plasma of  $kT_e \sim 23\text{--}30 \text{ keV}$  and an optical depth of  $\tau \sim 1.2\text{--}1.5$ , independent from luminosity of the system. This is a typical low hard spectral state for which the X-ray emission is attributed to the upscattering of soft seed photons by a hot, optically thin electron plasma. During the decay, spectra have a different shape, the high energy tail being compatible with a single power law. This confirm similar behavior observed by *BeppoSAX* during the previous outburst, with absence of visible cutoff in the hard X-ray spectrum.

*INTEGRAL*/JEM-X instrument observed four X-ray bursts in Fall 2007. The first one has the highest peak flux ( $\approx 3.5 \text{ Crab}$  in 3–25 keV) giving an upper limit to the distance of the source of about 5.7 kpc, for a  $L_{\text{Edd}} \approx 3.8 \times 10^{38} \text{ erg s}^{-1}$ . The observed recurrence time of  $\sim 1.2$  days and the ratio of the total energy

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emitted in the persistent flux to that emitted in the bursts ( $\alpha \sim 73$ ) allow us to conclude that the burst fuel was composed by mixed hydrogen and helium with  $X \geq 0.4$ .

*Subject headings:* gamma rays: observations – radiation mechanisms: non-thermal  
– stars: individual: SAX J1810.8–2609 – stars: neutron – X-rays: binaries

## 1. Introduction

The transient X-ray source SAX J1810.8-2609 was discovered on 1998 March 10 (Ubertini et al. 1998) with the Wide Field Cameras (2-28 keV) on-board the *BeppoSAX* satellite. During the performed Galactic Bulge monitoring, a strong type I X-ray burst was detected identifying this compact object as a neutron star in a low-mass X-ray binary system. Assuming standard burst parameters and attributing the photospheric radius expansion to near-Eddington luminosity, the distance was estimated to be  $\sim 5$  kpc (Natalucci et al. 2000). The wide-band spectral data (0.1–200 keV) obtained later with the NFI/*BeppoSAX* showed a hard X-ray spectrum described by a power law with photon spectral index  $\Gamma = 1.96 \pm 0.04$  and a soft component which was compatible with blackbody radiation of temperature  $kT \sim 0.5$  keV (Natalucci et al. 2000).

During a *ROSAT* follow-up observation on 1998 March 24 an X-ray source (named RX J1810.7–2609) was detected at a position consistent with the WFC error box (Greiner et al. 1998). Optical-to-infrared follow-up observations of the  $10''$  radius *ROSAT* HRI X-ray error box revealed one variable object ( $R = 19.5 \pm 0.5$  mag on March 13,  $R > 21.5$  mag on 1998 August 27) which was proposed as the optical/IR counterpart of RX J1810.7–2609 and SAX J1810.8–2609 (Greiner et al. 1998).

Using *Chandra* instruments, Jonker et al. (2004) detected the neutron star system in quiescence at an unabsorbed luminosity of  $\sim 10^{32}$  erg s $^{-1}$  (assuming a distance of 4.9 kpc). The quiescent spectrum is well-fitted with an absorbed power law with a photon index  $\Gamma = 3.3 \pm 0.5$  and the Galactic absorption value ( $N_{H,gal} = 3.3 \times 10^{21}$  cm $^{-2}$ ) consistent with the value derived in outburst.

Since 1998 this burster remained in a quiescent state. Only in August 2007 *Swift* observed a new phase of activity (Parson et al. 2007). The *Swift*/UVOT instrument detected a weak source in the white-band filter at the position of SAX J1810.8–2609 and did not detect it in any other single filter (Scady et al. 2007). The source was observed on a daily basis with *Swift* using  $\sim 1$  ksec exposure, starting August 6, 2007. In all observations the *Swift*/XRT 0.3 – 10 keV spectrum was well fitted using an absorbed power law model with a hydrogen

column density of  $N_H \sim 5 \times 10^{21} \text{ cm}^{-2}$  and a spectral index of  $\Gamma \sim 2$  (Degenaar et al. 2007). After few months, the source went back to quiescent state, indeed on November 3rd and 5th, *Swift*/XRT did not detect it during two individual  $\sim 1.6$  ksec and  $\sim 1.9$  ksec observations.

The X-ray spectra of LMXBs are usually fit with a complex model: at low energies a blackbody component that approximates the spectrum of an optically thick, geometrically thin accretion disk and/or the neutron star surface, and at higher energies a Comptonization component due to repeated inverse Compton scattering of the soft seed photons by hot electrons plasma with a thermal distribution of velocities. *BeppoSAX* and *INTEGRAL* results showed that the hard component can extend up to 200 keV without any appreciable break (Di Salvo et al. 2000, 2001, Fiocchi et al. 2006, Piraino et al 1999, Iaria et al. 2001, Tarana et al. 2006). In this paper, we study the spectral behavior of the X-ray transient burster SAX J1810.8–2609, showing this behavior during the decay of the outburst. Finally, we report on four X-ray bursts observed by *INTEGRAL*/JEM-X instrument in Fall 2007.

## 2. OBSERVATIONS AND DATA ANALYSIS

The *INTEGRAL* (Winkler et al. 2003) observations are divided into uninterrupted 2000 s intervals, the so-called science windows (SCWs). Spectra and light curves of the source are obtained using data from the two high-energy instruments JEM-X1 (Lund et al. 2003) in the 3 – 20 keV band and from IBIS/ISGRI (Ubertini et al. 2003) in the range 22 – 200 keV. The instrument data are extracted for each individual SCW and processed using the Off-line Scientific Analysis (OSA v7.0) software released by the *INTEGRAL* Scientific Data Centre (Courvoisier et al. 2003). Following the standard analysis, we use the latest response matrix with 64 channels. Then, data above 90 keV are rebinned to improve the signal to noise ratio. The *RXTE*/ASM (Levine et al. 1996) daily averaged light curve, provided by the ASM/RXTE teams at MIT and at the RXTE SOF and GOF at NASA’s GSFC, (Fig. 1, panel a, from [http://xte.mit.edu/ASM\\_lc.html](http://xte.mit.edu/ASM_lc.html)) shows that SAX J1810.8–2609 has been continuously active since beginning of August for two months with multiple peaks. The outburst of this transient source was frequently observed by *INTEGRAL* (Haymoz et al. 2007, Galis et al. 2007) during the Key Programme on the Galactic Centre and private Target of Opportunity observations.

The IBIS/ISGRI light curve (Fig. 1, panel b and c) shows a gradual brightening in two energy band, 22–45 keV and 45–68 keV, while the ASM peak intensity was not monitored with *INTEGRAL*.

We report here on the outburst emission measured by the IBIS/ISGRI instrument by

dividing it in four separate epochs (see Table 1). These correspond to time periods during which the source spectra appear quite stable, with very small or absent spectral variability as monitored on the time scale of a few SCWs.

We searched simultaneous IBIS and PCA (Glasser et al. 1994) data in the XTE public archive <sup>2</sup>, but unfortunately only for epoch 1 PCA standard products are available. No public PCA data are available for the epoch 2, 3 and 4. For our analysis we use the PCA standard products OBSID 93414-01-04-01. Data are collected in standard2 modes with a time resolution of 16s and 129 energy channels and from PCU 2 and PCU 4. Source and background spectra are generated with *SAEXTRACT* version 4.2d and response files with the tool *PCARMF* v10.1. Background rates were estimated using the epoch-5 models, as provided by the PCA calibration team.

### 3. SPECTRAL ANALYSIS

#### 3.1. The wide band outburst emission

The IBIS spectra extracted for the four epochs listed in Table 1 have been fitted with both a simple power law and a COMPTT model (Titarchuk 1994), assuming a spherical geometry for the Comptonizing region. Results are reported in Table 2. The temperature of the Comptonizing electrons  $kT_e$  and the plasma optical depth  $\tau_p$  were free parameters in the fit, while the temperature of the soft photon Wien distribution  $kT_0$  was fixed at 0.6 keV. This is

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<sup>2</sup> [http://heasarc.gsfc.nasa.gov/docs/xte/xhp\\_archive.html](http://heasarc.gsfc.nasa.gov/docs/xte/xhp_archive.html)

	Instrument	Tstart MJD	Tstop MJD	Exposure ksec	counts/s <sup>a</sup>
1	IBIS	54337	54357	572	5.80±0.07
2	IBIS	54358	54362	107	11.6±0.2
3	IBIS	54367	54370	121	10.9±0.2
4	IBIS	54373	54376	128	10.2±0.1
5	PCA	54345.49	54345.51	2	75.0±0.3

Table 1: Log of SAXJ1810.8-2609 IBIS and PCA observations.

<sup>a</sup> Rates are in the 22-200 keV energy range for IBIS and in 3-30 keV for PCA spectra. Source counts are background subtracted.

the value observed by *BeppoSAX* in 1998 and previously reported by Natalucci et al. (2000). Spectra are well described by a simple power law after the outburst peak, while a `COMPTT` model is required before the outburst peak. Using a thermal Comptonization model `COMPTT` instead of simple power law did not give significantly better fits for epoch 3 and 4, with the corresponding F-test chance probabilities being  $6 \times 10^{-2}$  and  $3 \times 10^{-3}$ , respectively. Instead this model is statistically highly significant for the epoch 1 and 2, with the corresponding F-test chance probabilities of  $4 \times 10^{-6}$  and  $2 \times 10^{-9}$ , respectively.

For the first period we build a spectrum in a broad energy band (3–200 keV), using simultaneous IBIS and PCA data. The most simple model which provides a good fit to this spectrum is made up of a thermal comptonized component `COMPTT` in XSPEC (Titarchuk 1994) with a spherical geometry plus a soft component consisting of a single temperature blackbody and an Gaussian component for iron line.

In the fitting procedure, a multiplicative constant has been introduced to take into account possible cross calibration mismatches between the soft X-ray and the *INTEGRAL* data; this constant has been found to be  $1.05 \pm 0.05$ . Results are reported in Table 2. The iron line centroid is  $6.3_{-0.4}^{+0.8}$  keV,  $\sigma_{\text{Fe}} < 0.6 \text{ keV}$  and equivalent width  $139_{-50}^{+43} \text{ eV}$ . Figure 2 shows four spectra and the residuals with respect to the corresponding best fits. Data and models are shown in Figure 3, for four epochs.

### 3.2. The bursts emission

In Fig. 4 and 5 we show the JEM-X 3–25 keV light curves for the four bursts.

The start time for each burst was determined when the intensity rose to 10 % above the persistent intensity level. The rise time is defined as the time between the start of the burst and the time at which the intensity reached 90 % of the peak burst intensity, as measured from the 2 s bin light curve in the full 3–25 keV band. The burst duration is the approximate time it takes to the 3–25 keV intensity (averaged over 3 consecutive bins) to decrease back to the average persistent level previous to the burst start.

The spectral analysis of the bursts is based on JEM-X data in the 3–25 keV band. Unfortunately, time resolved spectral analysis of such short bursts, requiring relatively high time resolution, leads to statistically poor results due to the little aperture of the JEM-X instrument. Therefore, a time-averaged spectral analysis over the first 18 s including the peak has been performed for each burst and every burst spectrum is well fit by a simple blackbody model.

The inferred blackbody temperature,  $kT_{\text{bb}}$ , and apparent blackbody radius at 5.5 kpc,

IBIS spectra Epochs 1, 2, 3, 4					
	$\Gamma$	$kT_e, E_c$ keV	$\tau$	$Flux_{20-100keV}$ $10^{-10} erg cm^{-2} s^{-1}$	$\chi^2_\nu$ $\chi^2(\text{d.o.f.})$
Power Law					
1	$2.30^{+0.10}_{-0.06}$	...	...	3.6	1.43[30]
2	$2.32^{+0.05}_{-0.06}$	...	...	7.5	1.49[29]
3	$2.67^{+0.07}_{-0.06}$	...	...	6.3	1.13[27]
4	$2.43^{+0.06}_{-0.05}$	...	...	6.0	0.92[32]
<i>comptt</i>					
1	...	$30^{+29}_{-7}$	$1.2^{+0.4}_{-0.7}$	3.6	0.70[29]
2	...	$23^{+8}_{-3}$	$1.5^{+0.4}_{-0.5}$	7.5	0.40[28]
3	...	$69^{+4}_{-4}$	$< 0.8$	6.3	1.02[26]
4	...	$87^{+5}_{-5}$	$< 0.8$	6.0	0.81[31]
IBIS and PCA spectra Epoch 1					
	$kT_{bb}$ keV	$kT_e$ keV	$\tau$	$Flux_{3-100keV}$ $10^{-10} erg cm^{-2} s^{-1}$	$\chi^2_\nu$ $\chi^2(\text{d.o.f.})$
1	$0.44 \pm 0.06$	$22 \pm 3$	$1.7 \pm 0.3$	8.1	1.05[78]

Table 2: Parameter values of spectral models fitting the outburst emission in the energy range 22-200keV using IBIS data and in the energy range 3-200keV using PCA plus IBIS data. Uncertainties are given at a 90 % confidence level.

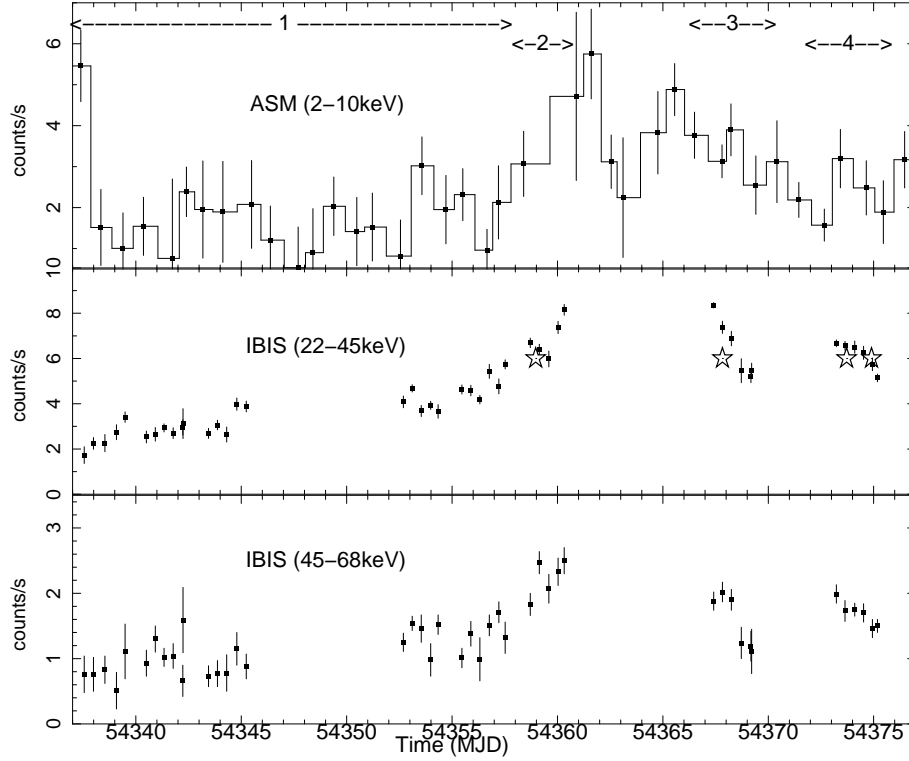


Fig. 1.— a) The RXTE ASM light curve daily averaged in 2-10 keV energy band of SAX J1810.8-2609. b) The IBIS light curve in 22-45 keV energy band. Stars indicate only burst times c) The IBIS light curve in 45-68 keV energy band.

$R_{\text{bb}}$ , for every burst are reported in Table 3. Burst fluences are obtained from the bolometric fluxes,  $F_{\text{bol}}$ , extrapolated in the 0.1–100 keV energy range and integrated over the respective burst durations. The peak fluxes,  $F_{\text{peak}}$ , are obtained by comparing the peak count rate of the 2 s bin light curves with the time-averaged count rate of the spectra modeled with a blackbody (see Table 3). Bolometric fluxes are extrapolated between 0.1 and 100 keV using XSPEC software. All uncertainties in the spectral parameters are given at a 90 % confidence level.

The first burst has the highest peak flux reaching a value of  $\simeq 500 \text{ cts/s}$  corresponding to  $\approx 3.5 \text{ Crab}$  ( $1 \text{ Crab} \approx 3 \times 10^{-8} \text{ erg cm}^{-2} \text{ s}^{-1}$  between 3–25 keV). From the light curve, it even seems to be preceded by a precursor 24 s in advance. However, since this burst was observed close to the limit of the JEM-X field of view, the significance of the precursor is quite low and therefore its reality may be doubtful. Assuming that the main peak flux corresponds to the Eddington limit for a helium burst,  $L_{\text{Edd}} \approx 3.8 \times 10^{38} \text{ erg s}^{-1}$ , as empirically derived by Kuulkers et al. (2003), we can calculate an upper limit to the distance of the source of

Table 3: Analysis results of the bursts

Dataset	Burst 1	Burst 2	Burst 3	Burst 4
Date (YYYYMMDD)	20070915	20070924	20070930	20071001
Start time (UTC)	23:20:18	19:52:50	17:10:03	21:42:10
$kT_{\text{bb}}$ (keV)	$1.4^{+0.4}_{-0.3}$	$2.1^{+0.2}_{-0.2}$	$2.6^{+0.3}_{-0.3}$	$2.5^{+0.5}_{-0.4}$
$R_{\text{bb,d}_{5.5\text{kpc}}}$ (km)	$18^{+20}_{-6}$	$6.1^{+2}_{-1}$	$4.1^{+2}_{-1}$	$4.5^{+2}_{-1}$
$\chi^2/\text{dof}$	17/27	40/43	30/24	31/57
$F_{\text{bol}}^a$	$4.5 \pm 2.3$	$2.8 \pm 0.8$	$2.7 \pm 0.7$	$3.0 \pm 1.3$
Burst parameters				
$F_{\text{peak}}^a$	$9.6 \pm 1.9$	$5.0 \pm 0.6$	$6.8 \pm 0.7$	$5.5 \pm 1$
$f_{\text{b}}^b$	$1.1 \pm 0.7$	$0.7 \pm 0.2$	$0.8 \pm 0.2$	$0.7 \pm 0.3$
Rise time ( $\pm 1$ s)	5	3	4	7
Duration ( $\pm 2$ s)	30	30	30	25
$\tau^c$	$12 \pm 9$	$14 \pm 5$	$12 \pm 4$	$13 \pm 8$
$\gamma^d$ ( $10^{-2}$ )	$0.9 \pm 0.2$	$1.0 \pm 0.2$	$0.9 \pm 0.2$	$0.8 \pm 0.2$

<sup>a</sup> Unabsorbed flux (0.1–100 keV) in units of  $10^{-8}\text{erg cm}^{-2} \text{ s}^{-1}$ . <sup>b</sup> Fluence ( $10^{-6}\text{erg cm}^{-2}$ ).

<sup>c</sup>  $\tau(\text{sec}) \equiv f_{\text{b}}/F_{\text{peak}}$ . <sup>d</sup>  $\gamma \equiv F_{\text{pers}}/F_{\text{peak,Max}}$ ;  $F_{\text{pers}}$  is the persistent flux in 0.1–100 keV energy range previous to the time of each burst,  $F_{\text{peak,Max}}$  is the highest burst peak flux, here  $F_{\text{peak}}$  of Burst 1.

about 5.7 kpc. For comparison, the theoretical value of  $L_{\text{Edd}} = 2.9 \times 10^{38} \text{ erg s}^{-1}$ , assuming a helium atmosphere, a canonical mass of  $1.4 M_{\odot}$  and 10 km radius for the neutron star photosphere (e.g. Lewin et al. 1993), leads to a distance of 5.0 kpc, consistent with the distance previously derived by Natalucci et al. (2000). The three remaining bursts are all weaker, reach approximately the same peak flux, and have similar decay times. From the detection of four bursts during the total observation time of about 928 ks elapsed on the source by *INTEGRAL*, due to the non continuous coverage of the outburst, we can estimate an approximate recurrence time of 2.7 days in average. Nevertheless, as the fourth burst occurred the day after the third burst, namely  $\Delta t_{3-4} = 102730 \text{ s} = 1.2$  days later, this interval represents a more stringent constrain on the bursting rate (see below).

The average persistent unabsorbed flux between 0.1–100 keV,  $F_{\text{pers}} \approx 5 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$ , translates to a bolometric luminosity  $L_{\text{pers}} \approx 1.8 \times 10^{36} \text{ erg s}^{-1}$ , assuming an approximate distance of 5.5 kpc. This corresponds to a mass accretion rate per unit area equal to  $\dot{m} = L_{\text{pers}}(1+z) \eta^{-1} \text{ c}^{-2}/A_{\text{acc}} \approx 10^3 \text{ g cm}^{-2} \text{ s}^{-1}$  (where  $A_{\text{acc}} = 4\pi R_{\text{NS}}^2$  and  $\eta = GM_{\text{NS}}/(R_{\text{NS}} \text{ c}^2) \simeq 0.2$  is the accretion efficiency for a canonical neutron star).



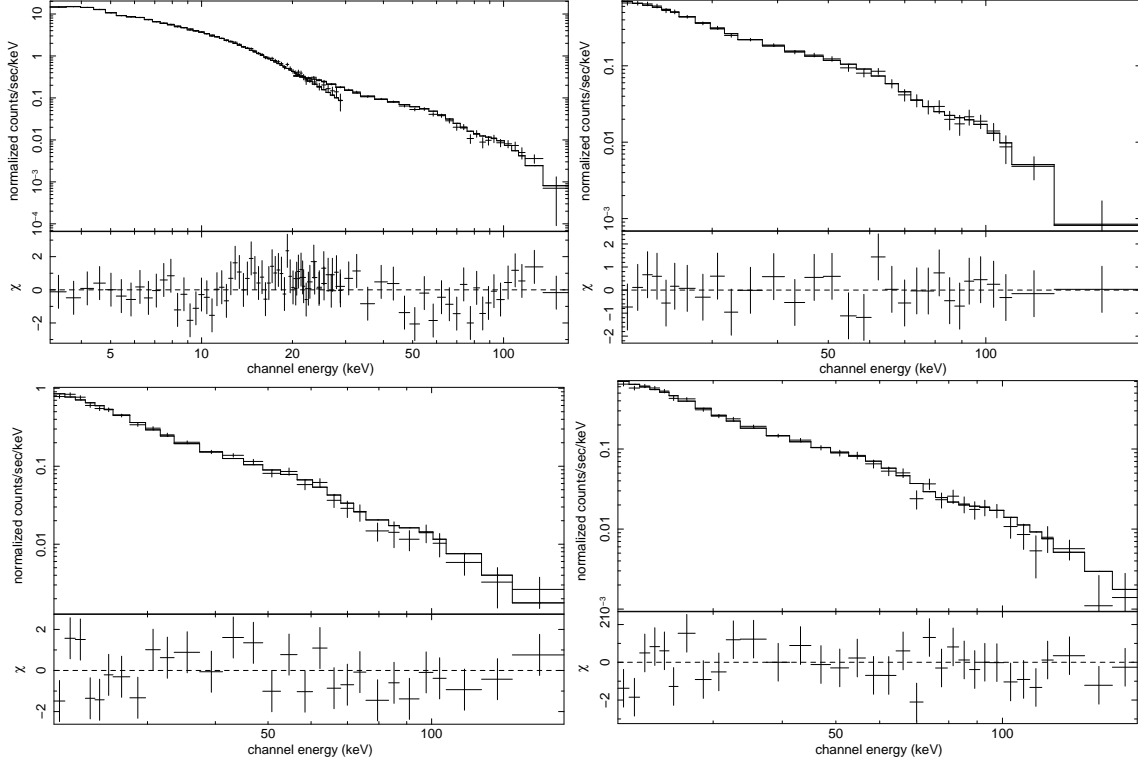


Fig. 2.— Four spectra of SAX J1810.8–2609 and the residuals with respect to the corresponding best fits, `COMPTT` plus blackbody component for epoch 1, simple `COMPTT` model for epoch 2 and simple power law component for epochs 3 and 4. For the epoch 1 spectrum is obtained using PCA and IBIS data (panel 1), while for others epochs spectra are obtained using only IBIS data (panels 2, 3 4).

The total energy released by the first burst was  $E_{b,1} \simeq 4 \times 10^{39}$  erg which, assuming complete and isotropic burning, corresponds to an ignition column  $y = E_{b,1}(1+z)/4\pi R_{\text{NS}}^2 Q_{\text{nuc}}$  ranging between  $y \approx 1 \times 10^8$  g cm $^{-2}$  for burning hydrogen with abundance  $X=0.7$ , and  $y \approx 2.6 \times 10^8$  g cm $^{-2}$  for  $X=0$  (pure helium); here  $Q_{\text{nuc}} = 1.6 + 4X$  MeV/nucleon is the nuclear energy release for a given average hydrogen fraction at ignition  $X$ , and  $z=0.31$  is the appropriate gravitational redshift at the surface of a  $1.4 M_{\odot}$  neutron star (Cumming, 2003). From the relation  $\Delta t_{\text{rec}} = y(1+z)/\dot{m}$  a burst recurrence time of 1.5 days is expected for  $X=0.7$ , and  $\Delta t_{\text{rec}} = 3.8$  days for pure helium burning. The same calculations for the fourth burst with an energy release of  $E_{b,4} \simeq 2.5 \times 10^{39}$  erg lead to  $\Delta t_{\text{rec}} = 0.9$  days for  $X=0.7$ , and  $\Delta t_{\text{rec}} = 2.3$  days for  $X=0$ . The observed recurrence time seems thus most consistent with mixed H/He burning.

Moreover, it is also possible to calculate the burst energetics by the ratio of the total

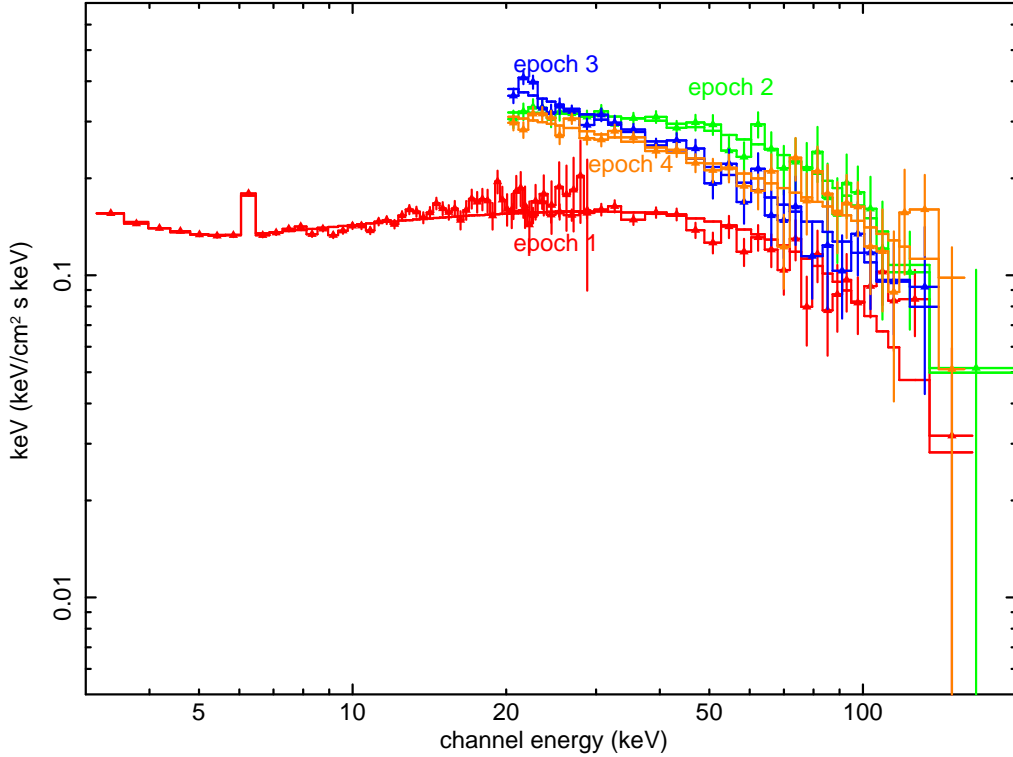


Fig. 3.— Four different spectral states with the `COMPTT` model. For the epoch 1 PCA and IBIS spectra are fitted (red color), while for others epochs only IBIS spectra are fitted (green, blue and orange colors).

energy emitted in the persistent flux to that emitted in the bursts (e.g. Galloway et al., 2004):  $\alpha = (F_{\text{pers}}/f_b)\Delta t_{\text{rec}} \approx 73$ , for  $\Delta t_{\text{rec}} = \Delta t_{3-4}$ ,  $F_{\text{pers}} = 5 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$ , and  $f_b \simeq 0.7 \times 10^{-6} \text{ erg cm}^{-2}$  is the fluence of the fourth burst. Assuming that all the accreted fuel is burned during the bursts, the calculated  $\alpha$ -value from the measurable quantities is consistent with  $Q_{\text{nuc}} = (1+z)\eta c^2/\alpha (10^{18} \text{ erg/g})^{-1} \simeq 3.2 \text{ MeV/nucleon}$ , corresponding to an hydrogen fraction  $X=0.4$ . Since other bursts could have been burnt during the observation gaps, the calculated  $\alpha$  value is only an upper limit and conversely the calculated value of  $X$  is a lower limit. We can indeed conclude that the burst fuel could be composed by mixed hydrogen and helium with  $X \geq 0.4$ .

#### 4. DISCUSSION

The IBIS/ISGRI observations have allowed us to follow the high energy behavior of SAX J1810.8–2609 during its long and bright X-ray outburst. Light curves varied simulta-

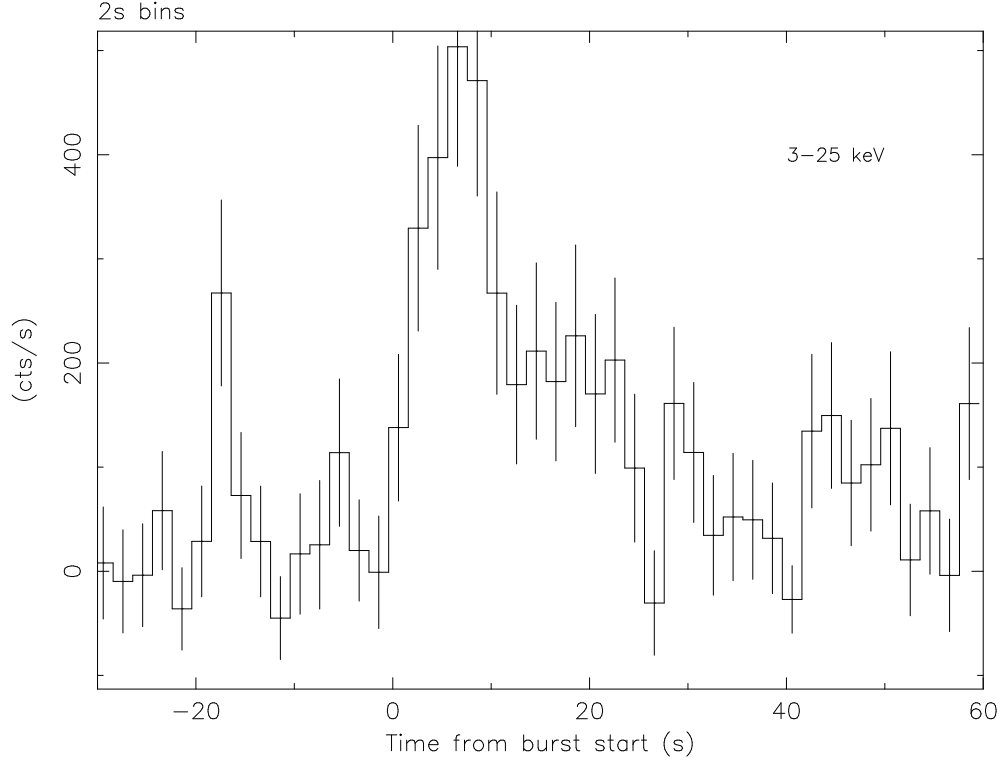


Fig. 4.— The first type I X-ray burst detected on September 15, 2007. Time 0 corresponds to 23:20:18 (UTC). The JEM-X (3–25 keV) light curve is shown with a time bin of 2 s.

neously in all X-ray bands monitored (2–10 keV, 22–45 keV, 45–68 keV). The X-ray spectra appeared always to be comparably soft, with a photon index of  $\Gamma = 2.3 - 2.7$ . The 20–100 keV luminosities are in the range  $L_X = 1.1 - 2.6 \times 10^{36} \text{ erg s}^{-1}$  (estimated for a source at 5.5 kpc), which is typical for the low hard state of neutron star binaries (Barret et al. 2000). We estimated a fluence of  $5.5 \times 10^{-3} \text{ erg cm}^{-2}$  using an average bolometric flux of  $1.6 \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1}$  in the 0.1–500 keV energy band and an outburst duration of  $\sim 40$  days from ASM light curve. The long term time averaged accretion rate is  $\dot{M} \simeq 5 \times 10^{-12} M_{\odot} \text{ yr}^{-1}$ , taking into account a time interval between two outbursts of  $\sim 9.6 \text{ yr}$ . The ASM, IBIS and BAT <sup>3</sup> light curves show the same behavior, so the outburst duration and the time between two outbursts are estimated using the ASM light curve. This time-average low mass accretion rate, the outburst luminosity of  $\sim 1 - 3 \times 10^{36} \text{ erg s}^{-1}$  lower than typical values for neutron star soft X-ray transient ( $\sim 2 \times 10^{38} \text{ erg s}^{-1}$ ), together with low quiescent

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<sup>3</sup>in the 15–50 energy range, from <http://heasarc.gsfc.nasa.gov/docs/swift/results/transients/weak/SAXJ1810.8-2609>

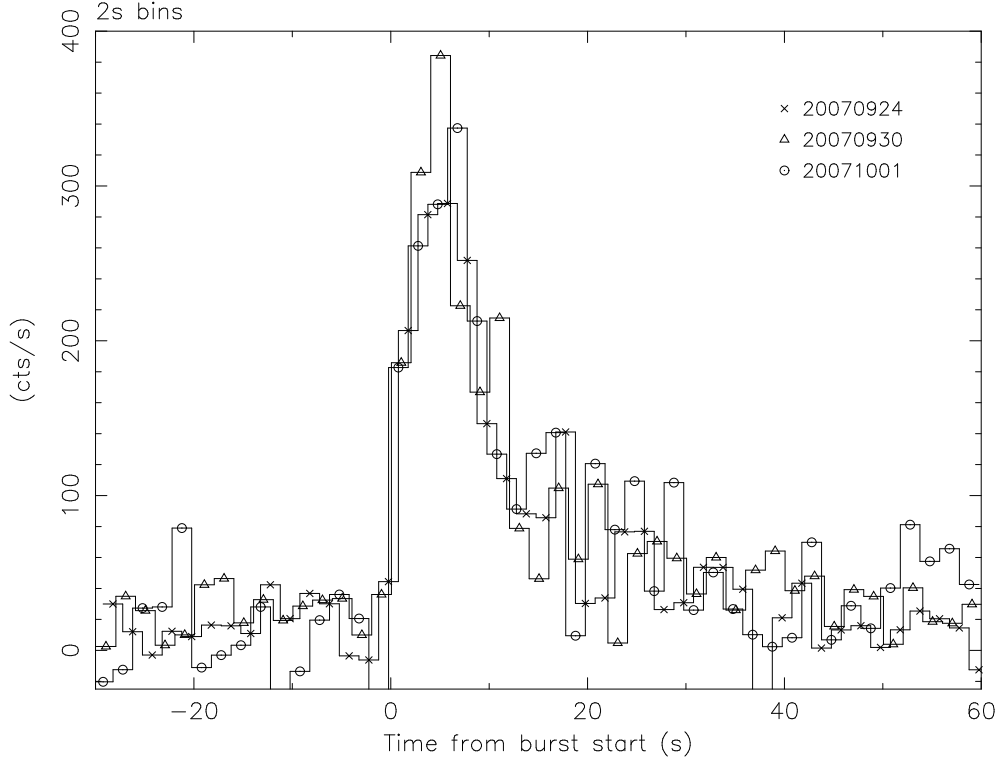


Fig. 5.— The three other bursts respectively detected on September 24, 30, and October 1st, 2007. The JEM-X (3–25 keV) light curves are shown with a time bin of 2 s.

luminosity ( $\sim 1 \times 10^{32} \text{ erg s}^{-1}$ ) reported by Jonker et al. 2004, strengthens the idea of these authors that this source belongs to the class of faint soft X-ray transient. In addition we note that the low average persistent bolometric luminosity is very similar as the luminosity of the Ultra Compact X-ray Binaries (see, e.g., Fiocchi et al. 2008 and Falanga et al., 2008). However, we think difficult to derive a conclusion about the ultra compact nature of the system because the derived hydrogen fraction in the burst fuel of SAX J1810.8–2609 is not consistent with an ultra compact source, since those are thought to accrete pure Helium from a white dwarf (Nelemans and Jonker, 2006).

Spectral parameters are not correlated with the observed luminosities, but instead, they vary according with the rise/decay phases of the outburst. During the rise of the flux, the SAX J1810.8–2609 luminosity changes by a factor 2, while there are not modifications of the spectral shape: the electron temperature  $kT_e$  is  $\sim 23\text{--}30$  keV and optical depth  $\tau$  of the plasma is  $\sim 1.2\text{--}1.5$ . This hard X-ray emission could be interpreted in the standard way, as produced by the upscattering of soft seed photons by a hot, optically thin electron plasma. During the decrease of the flux, spectra show a harder spectral shape with an optical depth

of the plasma lower than 0.8 and very high electrons temperatures  $kT_e$  of  $\sim 69$ -87 keV. The spectral parameters measured during the decay phase of the 2007 outburst agree with the ones found using the *BeppoSAX* observations (Natalucci et al. 2000), showing the same X-ray spectral behavior: during the decay phase of the outbursts of 1998 also no high energy spectral steepening was observed.

We cannot determine whether the emission is due to a thermal or non-thermal process, because equally good fits are obtained either with a power law with no detectable cutoff below  $\sim 100$  keV or with a thermal Comptonization spectrum with an electron temperature in excess of  $\sim 80$ -90 keV. This electron distribution could also arise from Comptonization by hybrid (thermal and non thermal) corona (Coppi 1999), or from the Compton cloud located inside the neutron stars magnetosphere (Titarchuk et al. 1996), or, alternatively, the power-law component could be produced by Comptonization of synchrotron emission in a relativistic jet (Bosch-Ramon et al. 2005, Fender 2004). Up to date there are few detections of radio emission associated with neutron star X-ray transients and sometimes outbursts of soft X-ray transient were associated with strong transient radio emission (Ball et al. 1995, Kuulkers et al. 1999, Fender & Kuulkers 2001). A comparison with hard tails detected from neutron star systems and some black hole binaries could be interesting suggesting that a similar mechanism could originate these components.

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